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COMPARATIVE EVALUATION OF THE APH-6D, HGU-35/P (LOW PRESSURE), --ETC(U)
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OMPARATIVE EVALUATION OF THE APH-6D, HGU-35/P (LOW PRESSURE), HGU-35/P (HIGH PRESSURE), VTAS II, VTAS III HELMET SYSTEMS ON THE DYNAMIC FLIGHT SIMULATOR

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30 DECEMBER 1976

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Pilots flying high performance aircraft under sustained acceleration in an ACM (Air Combat Maneuver) have been exposed to an additional stress imposed upon them by their heavy, unstable helmet and its related oxygen mask. A newly developed lightweight mold-in-place helmet with an integrated oxygen mask system was dynamically tested on the Naval Air Development Center (NAVAIRDEVCEN) human centrifuge in a simulated ACM acceleration profile. Four pilots, each wearing three variations of the prototype helmet, were exposed

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20. to a peak of 6 G_z in 10 seconds, held for approximately 4 seconds, returned to 2 G_z, then built up to 4 G_z in 10 seconds, held for approximately 4 seconds and then returned to a plateau of either 3 G_z or 1 G_z for a total time of 4 minutes. Performance measurements were made during the plateaus. The pilots used the APH-6 single visor helmet as a standard for the conventional HGU-35/P helmet and a VTAS-II helmet (lightweight, mold-in-place helmet assembly using an A-13A oxygen mask and an add-on VTAS electronic/optical system) as a standard of comparison for the VTAS-III (an HGU-35/P integrated oxygen mask system and an integrated VTAS electronic/optical system). Based upon a perfect score of 100, the overall evaluation of the helmets tested scored as follows: APH-6 (57.5), VTAS-II (46), HGU-35P High Pressure (79), HGU-35 Low Pressure (77.5, and the VTAS-III (71).

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S U M M A R Y

INTRODUCTION

A new series of lightweight, form-fit, mold-in-place helmets with an integrated oxygen mask system were exposed to high G acceleration tests under simulated altitude conditions of 8000 ft and 20,000 ft. A peak of 6 G_Z was reached in 10 sec and held for 4 sec, then the acceleration was reduced to 2 G_Z and again held for 4 sec and then returned to a plateau of either 3 G_Z or 1 G_Z for a total run time of 4 min. These acceleration/altitude tests were programmed on the NAVAIRDEVCEN human centrifuge in February 1975.

Prior to the NAVAIRDEVCEN human centrifuge acceleration/altitude tests, the HGU-35/P low pressure and high pressure oxygen masks were statically bench tested at the Crew Systems Department oxygen laboratory. These oxygen mask/helmet systems tests were followed up by a series of simulated altitude tests (sea level, 8,000 ft, 20,000 ft) in the hypobaric chamber located at the Philadelphia Naval Base.

Scope of Tests

Six helmet conditions were evaluated: (1) no helmet; (2) APH-6D single visor helmet with fitting pads and an A13-A oxygen mask (figure 1); (3) HGU-35/P low pressure helmet with mold-in-place fixed liners and an integrated oxygen mask (figure 2); (4) HGU-35/P high pressure helmet with mold-in-place replaceable liners and an integrated oxygen mask (figure 3); (5) VTAS-II single visor helmet with mold-in-place replaceable liners and an A13-A oxygen mask (figure 4); and (6) VTAS-III modified HGU-35/P low pressure helmet wi mold-in-place replaceable liners and an integrated oxygen mask (figure 5).

Two performance measurements were made on all helmet conditions: (1) head mobility and visual field perimetry, and (2) helmet sound attenuation. Indications of head and helmet stability were obtained additionally for the VTAS-II and VTAS-III helmets only.

The static bench tests of the oxygen breathing system were no-load measurements under three conditions. A 2100 psi oxygen tank was valved through a flow meter (liters/minute) into a "T" fitting connecting to a gauge (inches of H_2O) and to the oxygen mask supply hose (open-ended). Gauge measurements were made for each 10 liters/minute flow rate between 10 and 100. The oxygen hose was then connected to the helmet (without the oxygen mask) and again similar gauge measurements were made. Lastly, the oxygen mask was connected to the helmet and gauge measurements were made. These tests measured the resistance to oxygen flow caused by the oxygen hose, the helmet ducting, and the oxygen mask.

A leakage test was also performed on the oxygen mask supply hose. A 2100 psi oxygen tank was valved through a flow meter (cc/min) into a "T" fitting connecting to a gauge (inches of H_2O) and to the oxygen supply hose (closed end).

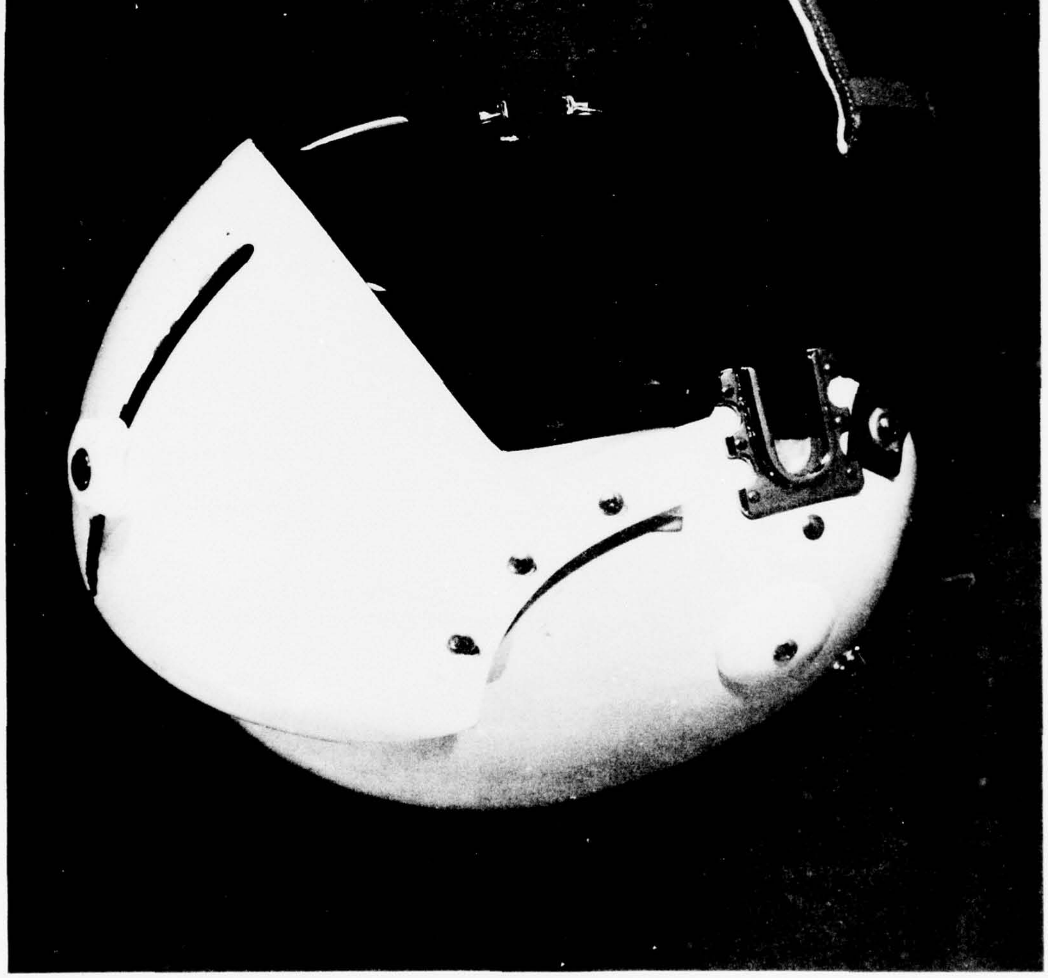


Figure 1. APH-6D (Single Visor) Helmet.

Figure 2. HGU-35/P Low Pressure Helmet.

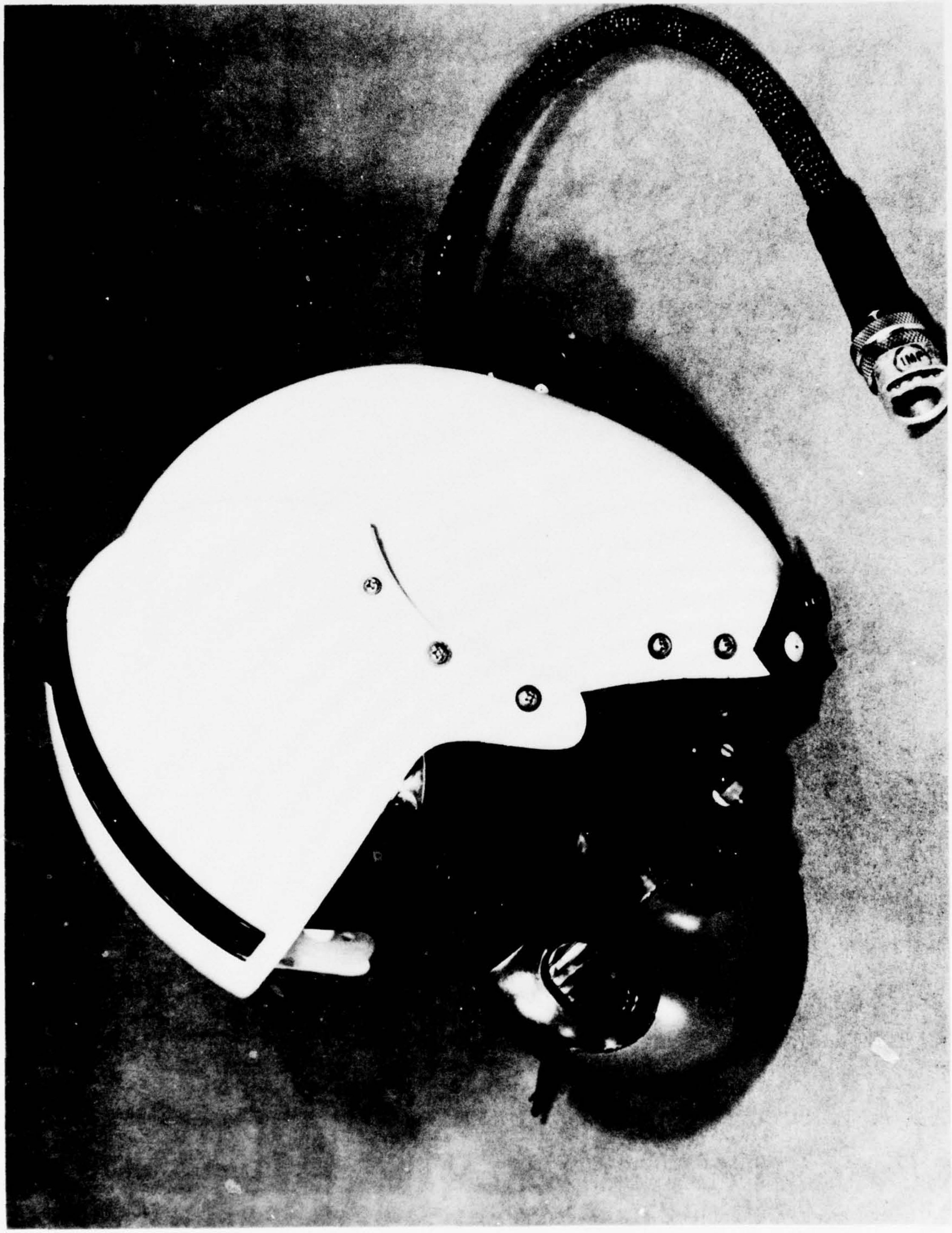


Figure 3. HGU-35/P High Pressure Helmet.

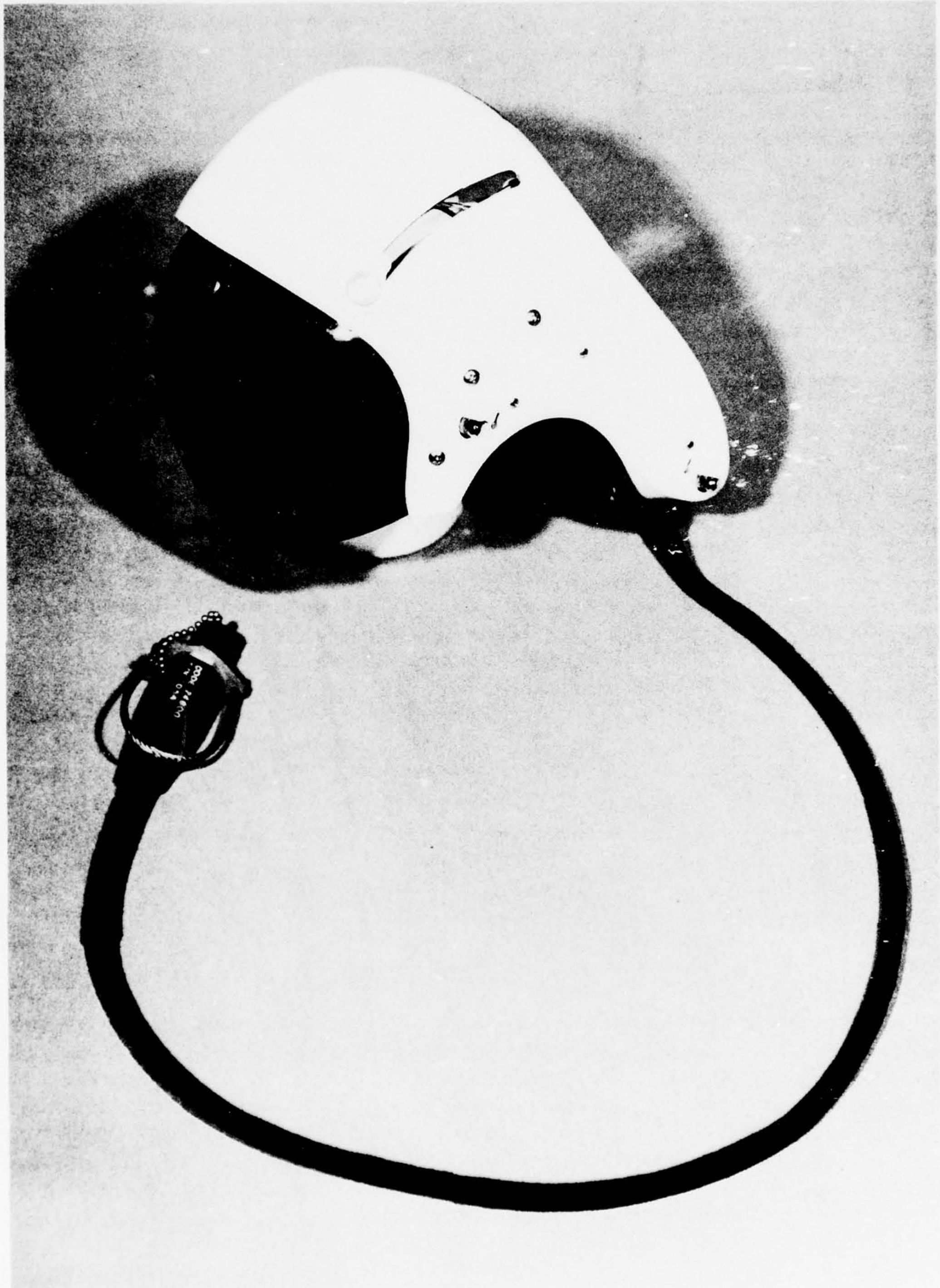


Figure 4. VTAS-II Visor Assembly.

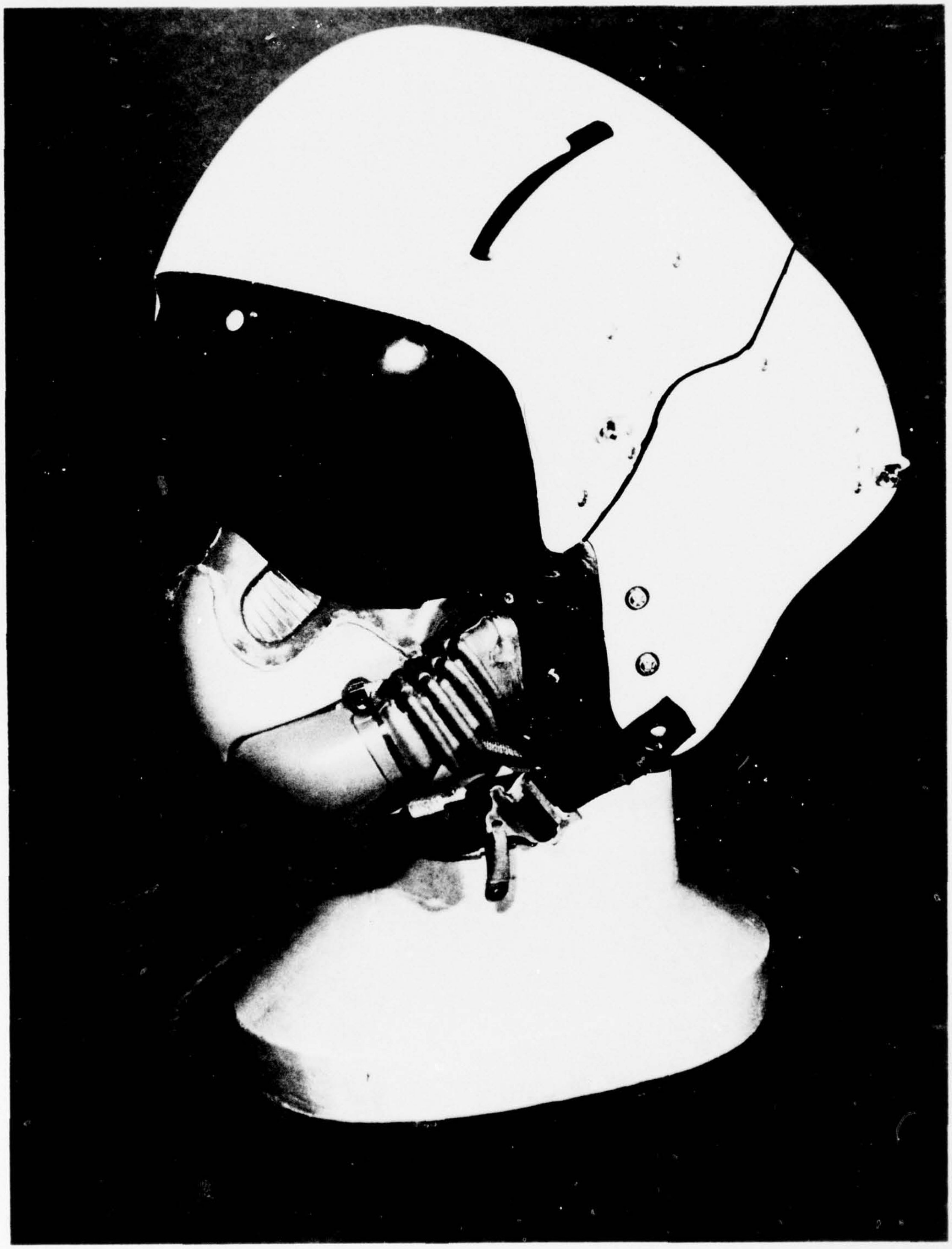


Figure 5. VTAS-III Helmet.

It was intended that the skin conductor capacitor microphone be used alternately with the mask-mounted dynamic microphone during the centrifuge testing program even though it was not a prime interest. However, there was an incompatibility between the power requirements of the skin conductor microphone amplifier and the power source in the centrifuge gondola which precluded the use of this microphone.

Conclusions

Based upon a perfect score of 100, the overall evaluation of the helmets tested scored as follows: APH-6 (57.5), VTAS II (46), HGU-35/P High Pressure (79), HGU-35/P Low Pressure (77.5), and the VTAS III (71). The concept of the lightweight, form-fit, mold-in-place helmet with an integrated oxygen mask was favorably received by all four pilots. However, many problem areas were identified and are presently being resolved.

The hypobaric chamber tests and the centrifuge simulated altitude tests indicated satisfactory operation of the helmet oxygen system.

Recommendations

The rear oxygen/communications and the VTAS III helmet connector on the HGU-35/P high and low pressure helmets should be relocated and redesigned to provide minimal discomfort and maximal compatibility with the seat headrest. It should also provide a more positive locking device.

The V-TEC liner and edge roll system should be redesigned to allow a larger space for a larger range of earcup adjustment.

The integrated oxygen mask suspension system is not properly aligned with the face and consequently causes leakage in the oxygen mask face seal. The right and left side helmet/mask connectors should be redesigned to allow for more face sizes and a better lock-on. The mask suspension system should also make provisions for in-flight adjustment.

The VTAS-III has a heavy visor assembly which moves the helmet center-of-gravity forward. Although the VTAS-III optics and electronics are not within the province of this report, serious consideration should be given to relieving this effect and reducing its overall weight in the future design of the ultimate VTAS helmet. Also the reticle projector vibrates under G forces and should be made more stable. The VTAS-III electronics power cord in the back of the helmet is very heavy and restricts mobility. This should be corrected.

The HGU-35/P low pressure hose is entirely unacceptable because of poor construction and requires redesign.

The HGU-35/P high pressure hose has a bulky and stiff coil at the back of the helmet which limits head mobility and comfort. A better design is needed.

The HGU-35/P low pressure oxygen mask requires a more positive acting inhalation/exhalation valve to reduce intermittent sticky and fluttering action.

The mask mounted regulator of the HGU-35/P high pressure mask is noisy and should be redesigned or its location changed.

In all designs of the HGU-35/P helmet (low pressure, high pressure, and VTAS-III), there should be some awareness to the pilot if the oxygen service hose is disconnected. Ambient air could be breathed in a low pressure condition without the pilot knowing it.

The form-fit liner systems have a heat build-up. The ultimate systems should have a means of thermal cooling.

I N T R O D U C T I O N

The Navy APH-6 Helmet has become a platform for the addition of new features of improvement such as dual visors, sound attenuating earcups and the VTAS (Visual Target Acquisition System). These have increased the bulk and weight of the helmet system to the point where they are unstable on the head under high "G" and too heavy to wear over a long period of time. The Naval Air Development Center and the Naval Air Systems Command have become aware of these problems and have developed new lightweight, form-fit, mold-in-place helmets with an integrated oxygen mask system. The weight of the helmet is reduced by a lightweight shell material and by the use of lightweight communication components and introducing a new skin conductor capacitor microphone placed on the earcup seal. The oxygen mask has been reduced in weight and profile and has become an integral part of the helmet system.

The HGU-35/P helmet is integrated with an oxygen mask breathing system. It consists of a lightweight DuPont Kevlar-49 shell with a layer of Nomex honeycomb in the crown area. The integrated oxygen mask has a combination inhalation-exhalation valve and a torso mounted regulator in line with a helmet mounted oxygen breathing hose. The regulated oxygen supply is fed into the back of the helmet through a combination oxygen/electrical rotating joint connector. The gas is then ducted internally within the helmet shell/liner system to the oxygen mask/helmet connector. It has a skin contact capacitor microphone with an alternate capability of a miniature dynamic mask microphone, miniature lightweight earphones, and a ratchet locking clear visor. The complete system weighs approximately 2.5 lbs compared to an APH-6 helmet/mask system weighing 5.2 lbs.

The HGU-35/P helmet high pressure oxygen breathing system is integrated with an oxygen mask having a mask mounted regulator. The high pressure oxygen supply passes through a lightweight high pressure oxygen hose into a smaller combination oxygen/electrical rotating joint at the back of the helmet. It is ducted through the helmet shell/liner system and mask/helmet connector to a regulator mounted within the mask. The obvious advantages of this system are that a decrease in hose bulk can be realized with no appreciable increase of system weight, and having a better oxygen flow characteristic.

The VTAS-II helmet assembly consists of a lightweight APH-6 fiberglass shell with a form-fit mold-in-place liner system and lightweight earphones. It uses a conventional A-13A oxygen mask system attached to the helmet with bayonet receivers. The VTAS-II sensor/electronics reticle projector and parabolic visor are contained in the visor assembly attached to the helmet.

The VTAS-III helmet assembly is a specially configured HGU-35/P low pressure, form-fit, mold-in-place helmet assembly. The VTAS electronics and sensors are fitted into the specially contoured helmet shell as an integral part of the helmet. The reticle projector is attached to the parabolic visor as part of the helmet system.

A preliminary concept evaluation program was conducted on the NAVAIRDEVCEN centrifuge to test the new lightweight integrated oxygen mask/helmet system at high "G" acceleration (Report No. NADC-75041-40 of 20 March 1975).

A second, and more extensive, centrifuge program was undertaken in January 1975 to evaluate four major points of view: (1) Engineering performance under an operationally realistic set of environmental conditions; (2) Physiological responses of the subjects as they wear each helmet; (3) Human Engineering Performance Capabilities of the subjects as they wear each helmet; (4) To assure that the helmet systems under study have a high probability to operate successfully in an aircraft high "G" environment and during ACM (Air Combat Maneuvers).

Four combat experienced pilots (LCDR Michael McCarthy, NAVAIRDEVCEN; LCDR Peter Angelina (NATC); LT Mark Gemmill (NATC), and LT Michael Samuels (NATC) were each form-fitted with mold-in-place HGU-35/P low pressure, high pressure, and VTAS-III helmets. An APH-6D helmet, a VTAS-II helmet, and a no helmet condition were used as baselines for the centrifuge runs and data analysis.

The centrifuge was controlled in open loop and simulated an F4 and F14 ACM profile with a peak of 6 G_Z in 10 sec, down to 2 G_Z at 20 sec, back up to 4 G_Z at 30 sec, and returning to a plateau of 3 G_Z or 1 G_Z (as the test program required) for a total time of less than 240 sec. Two performance measures were made: (1) Head mobility and visual field perimetry with the various helmets; (2) Helmet sound attenuation.

DESCRIPTION OF TEST PROGRAM

1. The experimental design for the helmet evaluation program consisted of the following:

a. Two Performance Measures

(1) Head mobility and visual field perimetry with various helmets
(2) Helmet sound attenuation
(3) For VTAS-II and VTAS-III helmets only: indications of head and helmet stability were obtained during additional data runs as cited in the run matrix.

b. Six Helmet Conditions

(1) No helmet
(2) APH-6 Single Visor and A13-A Oxygen Mask and Fitting Pads
(3) HGU-35/P Low Pressure Integrated Oxygen Mask with fixed liners
(4) HGU-35/P High Pressure Integrated Oxygen Mask with replaceable liners

(5) VTAS-II Single Visor and A13-A Oxygen Mask with replaceable liners
(6) VTAS-III Low Pressure Integrated Oxygen Mask with replaceable liners

c. Two "G" Plateaus

(1) 1 Gz
(2) 3 Gz

d. Four subjects

e. Two replications

This means there were 192 (2X6X2X4X2) basic experimental design data runs.

2. The no helmet condition and the APH-6 were used as two of the baselines for comparison of data. The reason for including the VTAS-II in these tests was to confirm that the VTAS-III, which was designed specifically for the requirements of high "g" environment, does offer greater stability, mobility and comfort.

3. Four pilots from the NAVAIRTESTCEN (Naval Air Test Center), Patuxent River, were used as subjects since they were already fitted with the HGU-35/P Low Pressure Helmets and had volunteered for the program. The pilots were required for a minimum of three test days.

4. The centrifuge was controlled in open loop and simulated an F4 and F14 ACM profile as shown in figure 6.

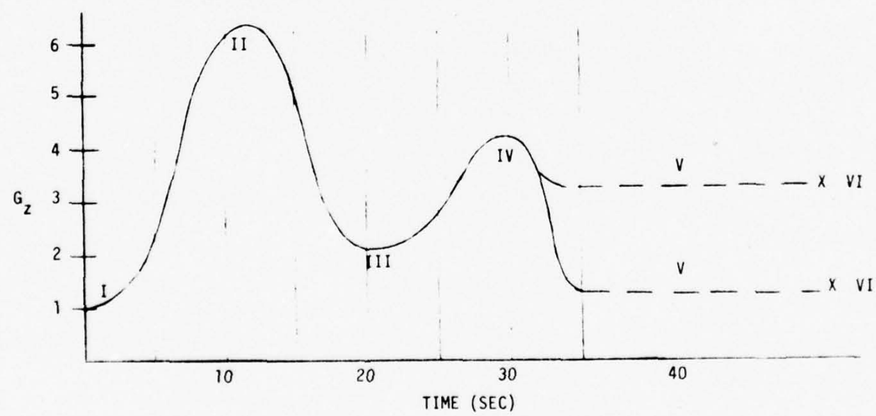
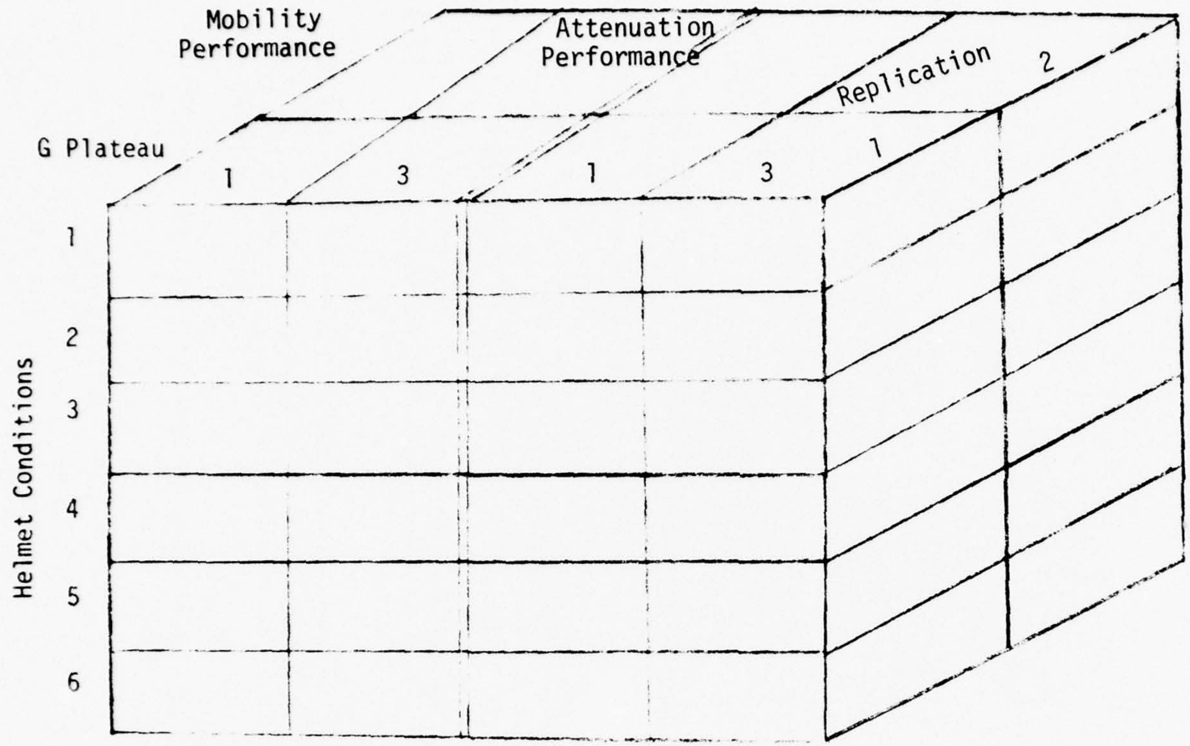


Figure 6. Time vs. G_z Curve.

5. Each data session was comprised of eight data runs (across two performance measures, two "g" plateaus and two replications) using one helmet condition. Each pilot/subject had to undergo six sessions, two sessions per day, therefore requiring three days per pilot to complete the experiment (figure 7).



NOTE: This matrix applies for each of the four subjects.

Additional Performance Runs

	VTAS RUNS (3G & Buffet)	
VTAS-II		
VTAS-III		

Figure 7. Run Matrix.

6. Vacuum caps were used on the gondola and all runs were made at a simulated altitude of 8,000 ft, except for the last run which was made at a simulated altitude of 20,000 ft using O_2 for breathing.

7. The pilot wore the helmet for one hour statically before entering the gondola. The gondola was decompressed to simulate 8,000 ft (this took approximately 90 sec) and then was exposed to peaks of 6g and 4g and then to a steady plateau of 1g or 3g for a total time of less than four minutes. The pilot then rested for three minutes before the next run. This sequence of test and rest was repeated until eight test runs were completed. (Approximately 50 minutes were required for each session.) On the last run, decompression from 8,000 ft to the pressure simulating 20,000 ft started 10 sec into the run. This took approximately one minute. When this run was completed, the gondola was returned to sea level pressure. This took approximately four minutes. The entire data session required approximately 60 minutes. The same series of runs was then repeated with another pilot.

8. The reason for testing at 8,000 ft simulated altitude was that the medical monitor wanted the testing to be accomplished at an operationally realistic altitude in order to get information concerning mask operation configuration, combined with the effects of a high "g" environment.

9. The reason for testing at 20,000 ft simulated altitude was that the medical monitor wanted to know how the mask functioned after decompression to this arbitrarily chosen altitude while exposed to a "g" environment.

10. The physiological/medical monitoring/data portion of the helmet evaluation program was not intended to make definitive judgments concerning the comfort or performance of any of the helmets, but establishes the subject's well-being while exposed to the test profile. The significant changes found in the various physiological parameters studied are not necessarily due to the helmets being tested. The criteria for subject selection was the same as that utilized in any of the centrifuge studies carried out at the NAVAIRDEVCEN, namely, a current flight physical examination, including ECG, a complete spinal series of X-Rays, blood biochemical and hematological work-up, and a psychological examination. All subjects were briefed on the medical aspects of the program.

Each morning the subjects were given a complete physical examination including ECG, urinalysis, and blood work. The first subject was then instrumented with the ECG electrodes (Parke-Davis Co.) for use in the gondola. A chest lead utilizing two "active" and one "neutral" electrodes is the standard ECG arrangement. Continuous ECG is a requirement for all centrifuge experiments. The subject then donned whichever helmet he was scheduled to wear for that particular series of tests.

In order to measure Sweat Response, a pair of skin resistance electrodes was attached to the subject's forehead and he sat completely idle for a period of one to one and one-half hours, with the skin resistance on his forehead monitored every minute by use of an ohmmeter. This information would determine the relationship between each type of helmet and the onset of sensible perspiration, which was indirectly detectable by monitoring skin resistance variations.

A thermistor (Yellow Springs, Inc.) was mounted inside the helmet and a minute-by-minute record was kept of the temperature within the space between the helmet and the subject's head. This information determined whether there was a difference between helmets, in intra-helmet temperatures, as the run progressed, and how much difference.

When the subject was ready to be installed in the gondola, he was fitted with six EMG (electromyogram) electrodes (Microcom Corp. Biodes). They were placed on the subject's sternocleidomastoid and trapezius muscles in order to give some objective indication of how much difficulty was encountered in maintaining the head erect, under G, while wearing the various helmets. A comparison of this data with the performance data will indicate the effects of fatigue as a result of maintaining head position. It is believed that the lighter the helmet and the closer the c.g. is to the support column, the less the EMG activity. EMG should be a direct physiological indicator of good helmet design. The subject was then outfitted with the rest of his normal flight gear which included flight suit, torso harness, survival vest, G suit, oxygen mask, helmet, gloves and flight boots; and installed in the gondola.

Once inside the gondola, the ECG, EMG, gondola temperature, the subject's rectal (core) temperature, and intra-helmet temperature were continuously monitored on the externally located medical/physiological monitor's station. The medical monitor's console consisted of a Brush Model 481-8 channel Strip Chart Recorder for a permanent record of all parameters, and a Tektronix Model K13 Storage Display/Tektronix Model 4701 eight Channel Multiplexer for real-time monitoring and display of ECG.

At the end of each exposure, of which there were nine or eleven sessions, depending on which helmet was being evaluated, the medical monitor asked the subject for subjective comments concerning his previous ride and of the subject's physical condition. All of these questions and answers, as well as the subject's visual appearance within the gondola during his centrifuge exposure runs were recorded on video tape using a Sanyo Video Tape Recorder connected to a closed circuit TV camera located within the gondola. The closed circuit TV camera observing the pilot's face is a mandatory requirement for all centrifuge operations.

Following the final exposure of a testing session, the subject was egressed from the gondola and taken immediately to the Subject Preparation Room where he underwent a complete post-flight physical examination, including ECG, urinalysis, and blood-test chemistries. He was then given a thorough medical debriefing, using specially prepared questionnaires (see Tables 1, 2, 3, 4, 5). In addition, the subject was also given a debriefing by the Human Performance Team to ascertain the subject's comments about the various helmets he was wearing.

11. The following performance measurements were observed and recorded:

a. Visual Field Perimetry - To determine the range of the visual field provided by each helmet, visual field perimeters were measured with each pilot wearing each of the five helmets under laboratory test conditions.

b. Head Mobility Measurements - To evaluate the constraints imposed by the helmets on head mobility, each subject was required to move his head and identify

TABLE 1

MEDICAL PRE-RUN QUESTIONNAIRE

Medical Complaints - None - 12
Yes - 3 Recent nose bleed
Slight nasal congestion
URI

Hours slept - 6 hours - 4
6.5 hours - 1
7 hours - 6 Average - 6.8 hours
7.5 hours - 2
8 hours - 3

Rested completely - 11
somewhat - 4

Sleep restful - 13
fitful - 22

Last meal - 1 hour - 5
2 hours - 5
4 hours - 3 Average - 3.6 hours
13 hours - 1
14 hours - 1

Medications No - 10
Yes - 4 Tetracycline 250 mgm po x2 - 3 hours pre
ASA - 20 hours pre
Alka-Seltzer - 9 hours pre

Ethanol No - 9
Yes - 5 16 oz - 12 hours pre
8 oz - 11 hours pre
8 oz - 10 hours pre
3 oz - 10 hours pre

Present physical condition Excellent - 8
Good - 6

Exercise Every day - 0
1x week - 4
2x week - 10

Physical problems - chronic None - 10
Yes - 1 Stomach and intestinal problems 2° to ETOH ingestion
Hemorrhoids

TABLE 2

MEDICAL POST-RUN COMMENTS

Tired	- 11
Greyout	- 9
Tape on biosensors uncomfortable	- 5
Vertigo	- 5
Abdominal discomfort 2° to G suit	- 6
Dizziness	- 4
Shaky	- 3
Relaxed	- 3
Thirsty	- 3
Physically uncomfortable in gondola	- 2
Biosensors uncomfortable - EKG and EMG loose	- 2
G-suit over-inflates	- 2
Weak	- 2
Hungry	- 2
Depressed	- 2
Stick not back far enough	- 2
Discomforting - 3 G with buffet	- 2
Ride uncomfortable at max G	- 1
Difficulty breathing - G suit too tight	- 1
All EMG leads uncomfortable	- 1
Elated	- 1
Nausea with helmet mobility at 3 G	- 1
G loading unrealistic	- 1
Stuffy in gondola	- 1
Light-headedness	- 1
Cold sweats	- 1
Visual problems 2° to light-headedness	- 1
Abdominal "gas" pains	- 1
Throat dry	- 1
Nausea	- 1
Rectal probe uncomfortable	- 1
Torso harness uncomfortable	- 1
Straps (torso) not attached correctly	- 1
Some apprehension before run	- 1
Increased salivation	- 1
Mike ride-up on front of teeth	- 1
Pain R side head - ear cuff	- 1
Pressure point - top of head - APH-6	- 1
Pressure point side of nose - mask - APH-6	- 1
Mask unsatisfactory - helmet worse - APH-6	- 1
02 mask loosens up on R side and pulls down on nose - bottom presses on throat	- 1
Mask valve flutters - exhalation	- 1
Valve tends to stick	- 1
Pressure point inside helmet 2° to hose	- 1
Pressure point - helmet liner - HGU-35/P (HP)	- 2
02 mask leaks L top side - HGU-35/P (HP)	- 1
Coil for 02 uncomfortable - HGU-35/P (HP)	- 1
02 mask loose and noisy - HGU-35/P (HP)	- 1
02 mask too short - pressure against bridge of nose - HGU-35/P (HP)	- 1
02 mask uncomfortable - binds nose - HGU-35/P (HP)	- 1
02 mask does not fit helmet - HGU-35/P (HP)	- 1
Helmet and mask unsatisfactory - HGU-35/P (HP)	- 1
L retro-auricular region burned by faulty mike - HGU-35/P (LP)	- 2
Helmet heavy, but comfortable - VTAS II	- 1
"Not thrilled" with VTAS III tracking task	- 1

Estimated recuperation time before ready for next run:

2 min	- 1
25 min	- 1
30 min	- 1
1 hr	- 4
1.5 hr	- 3
2 hr	- 5
5 hr	- 1
24 hr	- 2
1 yr	- 1
10 yr	- 1

TABLE 3

SUBJECTIVE REPORTS

Immediate Post Run

Dizziness	- 7
Abdominal discomfort	- 5
Neck pain/stiffness	- 4
Fatigue	- 7
Muscular pain/swelling	- 2
Headache	- 2
Dry throat	- 2
Weakness	- 1
Nose sore	- 1

24 Hours Post Run

Muscle pain/swelling	- 2 (trap.)
Fatigue	- 2
Clavicle pain 2° to harness	- 1
Neck pain/stiffness	- 1
Joint pain/swelling	- 1
Weakness	- 1
Abdominal discomfort	- 1
Headache	- 1
Dry throat	- 1

General Opinions of Ride

Pre:

Fine	- 5
Interested	- 4
Willing to ride	- 2
Well motivated	- 2
"I signed up, I'll ride"	- 1
"I'll do it"	- 1
Relieved	- 1
It's O.K.	- 1
Was "forced into it"	- 1
Ready to go	- 1
Wants to "get it over with"	- 1

Post:

O.K.	- 4
Good	- 3
Likes ride	- 2
Relieved	- 2
"No"	- 2
Helps to understand problems	- 1
Buffeting unrealistic	- 1
Enjoyed run	- 1
Easy one of all	- 1
Boring	- 1
Depressing	- 1
Not bad	- 1
Interesting, but not overly so	- 1
Do not see reason for duplication	- 1
No ventilation at altitude	- 1
"Drag", in general, after a few runs	- 1
All right for a visit	- 1
So-so	- 1
Rather be in Philadelphia	- 1
O.K., but disappointed in audio-task	- 1
Whole ride discomforting (APH-6)	- 1
Excellent way to obtain baseline (in what helmet/mask should *not* be [APH-6])	- 1

TABLE 4

PRE- AND POST-RUN PHYSICAL EXAMINATIONS

PHYSICAL EXAMINATION:

Pre		Post	
Hyperemia retro-pharynx	- 5	Cutaneous hyperemia/ecchymosis	- 7
Nasal hyperemia	- 4	Lungs clear	- 7
Sub-crepitant diffuse basal rales	- 3	Ecchymosis/hyperemia-abdomen	- 6
Occ. wheezing	- 3	Ecchymosis/hyperemia-clavicle	- 5
2° degree burn behind L ear	- 2	Ecchymosis/hyperemia-nucal region	- 5
Hyperemia R-L T.M.	- 2	Ecchymosis/hyperemia-legs	- 3
Ecchymosis L abdomen	- 1	Ecchymosis/hyperemia-sternum	- 3
Coarse breath sounds	- 1	Ecchymosis/hyperemia-back	- 2
Hyperemia shoulders (straps)	- 1	Ecchymosis/hyperemia-L flank	- 2
		Pain nucal region	- 5
		Pain mesogastrium	- 3
		Lessening of hyperemia retro-pharynx	- 2
		Lessening of hyperemia nose	- 2
		2° degree burn behind L ear	- 2
		Lessening of hyperemia R TM	- 1
		Wheezing L base	- 1
		Diffuse sub-repitant rales - base	- 1
		Hyperemia-nose	- 1
		Hyperemia-neck	- 1

VITAL SIGNS:

Blood pressure--standing--average 135.1/83.4 pre systolic--n.s.
130.9/84.2 post diastolic--n.s.
supine --average 131.2/79.83 pre systolic--n.s.

diastolic standing vs diastolic t = .1 (90%) (pre)
diastolic standing vs diastolic supine t = .1 (90%) (post)

Pulse--pre--79.5/'
post-89.1/' t = .005 (99%)

Temperature--pre--98.5°
post-99.2° t = .005 (99%)

Respirations--pre--22.6
post-23.1 t = n.s.

T A B L E 5

EKG CHANGES - PRE-POST RUN

PRE- POST
RATE CHANGES:

85 - 95	
70 - 50	
87 - 75	
70 - 72	
58 - 47	
56 - 52	
49 - 54	
53 - 43	mean - 69.3 - 64.8
85 - 75	non-significant
80 - 85	

PR CHANGES:

.16-.17	
.14-.16	
.14-.16	mean - .15 - .16
.20-.18	
.12-.14	non-significant

QRS CHANGES:

.08-.10
.10-.08

RT CHANGES:

.28-.30
.32-.30

AXIS CHANGES:

20°-(-)20°

COMPLEX CHANGES:

PRE- POST			PRE-POST		
RSR - QRS	Fig. 1 - III	1	+T--±T	AV1	1
Depress ST - nor ST	Fig. 1 - III	1	flattening of p	V1-V6	1
±T--+T	Fig. 1 - III	3	-p--+p	AVf	1
-T--+T	Fig. 1 - III	1	±p--+p	AVf	1
±T---	Fig. 1 - III	2	+p--(-)p	Fig. 1-I, AV1	1
+T--±T	Fig. 1 - II, AVr AVf	1	+p--±p	Fig. 1-II, AVr	1
			q	Fig. 1-I	1
			QRS--qrs	Fig. 1-II, AVr, AVf	1

a visual numerical display that was located above and directly behind him, behind him and to his right, and behind him and to his left. A signal light indicated the beginning of each trial, and the subject moved his head, terminated the display, and reported its numerical value. The subject responded by means of a stick-mounted trigger switch. Three trials were used for each display in each run. Trials were separated by a minimum of 15 sec.

c. Sound Attenuation Measurements - To evaluate the adequacy of the helmets for speech communication purposes, audiometric techniques were used to measure the relative sound attenuation of the helmets across the experimental conditions. Center test frequencies of 500, 1K, 2K, and 4K Hz were programmed by a Bekesy audiometer to a gondola-mounted speaker. The frequencies selected approximated the mid-range of 4 frequency bands of equal contribution to speech intelligibility.

Subjects responded by means of a stick-mounted trigger switch. For these measurements, the earphones were disconnected from the communications system (with medical monitor over-ride).

d. Speed and Pattern of Head Movements - To determine the speed and pattern of the pilot's head movements under the various helmet/g conditions, movements of the head and helmet were recorded on video tape.

e. Stability of VTAS Helmets - To determine the stability of the VTAS-II and VTAS-III helmets, two additional runs were made in which pilots attempted to keep a target light aligned with the reticle in the VTAS helmets while under conditions of $3G_Z$ and buffet ($\pm$ .3G @ 10HZ). Pilots depressed a trigger switch while the target was maintained in the reticle, and released the switch when the target was not maintained.

f. Subjective Evaluation of Helmets - A detailed questionnaire and in-depth interview was conducted with each pilot subject in this study. Problem areas were identified, and pilot's recommendations were solicited.

12. Data Collection Schedule

Code

1 = no helmet
2 = APH-6D
3 = HGU-35/P (H.P.)
4 = HGU-35/P (L.P.)
5 = VTAS-II
6 = VTAS-III

	Pilot Number			
	McCarthy No. 1	Samuels No. 2	Angelina No. 3	Gemmill No. 4
1st day				
a.m.	2	4	4	1
p.m.	1	2	3 (Run aborted. O_2 connector problem. Re-run on 2/12)	6
2nd day				
a.m.	3	5	5	2
p.m.	5	6	1	3
3rd day				
a.m.	6 (Incomplete) Completed 2/13	1	2	5
p.m.	4	3	6	4

13. Medical Safety Protocol

1. Subject Pool

The subjects were four volunteer jet fighter attack pilots. Each subject rode the centrifuge twice each day for three days with a period of about three hours between each ride.

Apparel:

Flight suit
Torso harness
Survival vest
G suit
Oxygen mask
Helmet
Gloves
Flight boots

2. Conditions for Stopping Run

a. at subject's own request
b. any medical emergency
c. at flight surgeon's/flight director/computer operator discretion

3. Medical "In Flight" Monitoring

a. There was a closed circuit TV monitoring installation, with the subject's face and eyes clearly visible under all test conditions.

b. constant two-way voice communication.

c. Specific medical monitoring was included, with a graphic runoff of same, used on each subject during each run, as follows:

(1) EKG
(2) EMG--trapezius and sternocleidomastoid
(3) Perspiration receptor
(4) Gz
(5) Thermometer (rectal, in helmet, in cockpit)

d. There was a "stop the run" switch at easy access to the subject

e. Subjective comfort chart post every run.

4. General Considerations - Medical Team Concept

Four hospital corpsmen, supplemented by other military personnel, were assigned to assist the medical officer. The dispensary, with its ambulance, was on an "on call" basis, in the event that an emergency requiring such services occurred. The mission of the team was to be able to effectively manage all medical emergencies from occurrence through stabilization, and evacuation to definitive care or hospitalization, without assistance.

A "pre-run" physical examination of the subject was conducted by the flight surgeon in the designated private area (prep room), with only key medical personnel present. An immediate screening post-run evaluation was made at the conclusion of the session after the subject was removed from the vehicle by flight surgeon and two designated corpsmen. A complete "post-run" physical examination and interview were conducted in an uncomplicated atmosphere on site in relative privacy after the subject was cleared by the immediate evaluation. Upon completion of the examination, the project engineer was granted access to the subject for program debriefing.

5. Subject Selection Criteria

For the purpose of the Helmet Evaluation Project sessions, all subjects were active duty military jet fighter attack pilots selected on a voluntary basis from Patuxent River and NAF Warminster flight personnel, and there was a total of four subjects. These subjects were found qualified for such duty on the basis of a thorough flight physical examination within 12 months prior to participation. Preflight instructions established subject familiarity with the centrifuge, the program in general, and the possibilities for potential injury, as well as could be ascertained. Under no circumstances was any subject exposed to any test condition without his "enlightened" consent. Each subject signed a "Voluntary Consent" form prior to commencement of the project. Each subject was given prior instructions of possible hazards of each condition, safety precautions to be taken, and in the use of all equipment. He was also briefed on the progress of the project at each session and an active participation and interest on the subject's part was encouraged. It was recognized that the criteria devised in advance could not adequately encompass all potential medical anomalies or injuries. However, a list of arbitrary criteria was presented and considered.

All subjects were free of a positive history of hypertension; cardiac abnormalities, disease, and/or arrhythmias; thromboembolic phenomena; bleeding disorders, herniations, and surgical interventions in truncal region.

All subjects were evaluated individually in the case of the presence of nasal airway blockage (polyps), obesity, active respiratory -- or other type -- infection, and recent joint injury, and kidney disease.

No criteria, as described above, could adequately encompass all potential medical anomalies or injuries; therefore, the ultimate decision in each category rested with the medical officer, with the arbitrary criteria listed above serving primarily as a guideline to aid the medical officer in her decision-making.

6. Examination

All subjects had a complete physical examination within 12 months preceding participation in the study. This examination was a standard flight physical examination, and the subjects did not have any injuries or illnesses within the time since their passing this examination which would eliminate him (them) on the basis of the hazardous duty requirements.

The examination included the following, in addition to data obtained during the clinical evaluation:

a. dental examination
b. urinalysis
c. CBC
d. EKG - 12 lead
e. chest x-ray - PA and lateral(L)
f. lumbral-sacral-thoracic-and cervical spine x-rays - AP and lateral
g. opthalmologic examination
h. audiometry
i. complete mental status examination

Also, as a baseline, the following blood chemistries, hemograms, and urinalysis were obtained on each subject prior to entry into the program for use thereafter in comparison studies, and were done before and after each session on each subject:

a. creatinine
b. bilirubin - total
c. phosphorous
d. alkaline phosphatase
e. uric acid
f. cholesterol
g. total protein
h. calcium
i. BUN
j. glucose
k. LDH

l. SGOT
m. SGPT
n. CPK
o. albumin
p. CBC with differential
q. urinalysis with microscopic

All subjects were free of x-ray and physical examination evidence of skeletal defects (e.g., moderate to severe scoliosis/kyphosis, spina bifida occulta, or early degenerative changes). A review of suspected cases by the flight surgeon, and/or orthopedic service was done.

Fractures of long bones and/or spine, occurring during a period greater than 12 months prior to entry into the program (e.g., long bones of extremities, clavicle, scapula), were reviewed by the medical officer and/or the orthopedic and radiology services, and certified as well healed on the basis of clinical and radiological criteria (e.g., full return to function, alignment on x-ray, etc.). (See OPNAV Instruction 3750.6H.)

No subject was considered with a history of flexion/extension injury, as defined by manifestations of symptoms of limitation of range of motion of the head and neck and/or localized (to the neck) muscle spasm, but with absence of x-ray findings, with persistence of such signs/symptoms for a period of greater than 48 hours, within six months before the beginning of this program.

14. Human Factors Test Program

a. At the beginning of the experimental program, S was briefed on the performance measures to be taken. In addition S read the instructions and the questionnaire that he would complete to evaluate each helmet system.

(1) Helmet and Mask Evaluation. When you come out of the centrifuge gondola, you will be asked to rate the helmet and mask that you have worn. You will rate helmet and mask characteristics having to do with comfort, vision, performance under G, etc. These ratings should be in terms of fleet use in fighter and attack aircraft and should be based on your experience with the helmet and on your knowledge of fleet environments and fleet requirements.

The rating scales are numbered 0 to 100, with low numbered ratings being worse and high numbered ratings being better. The points 0 and 100 on the scale represent extreme values for actual helmets to be considered for fleet use.

In addition to the ratings of the helmet and mask characteristics, we will ask you to rate the relative importance of each characteristic. That is, you will rate how large a contribution a high or low rating of a particular characteristic would make toward your overall ratings of the helmet and mask.

The scales used in rating the helmets do not have labels such as "Excellent", "Poor", etc., since more accurate ratings can be achieved without them. However, after you have completed the regular ratings, we will ask you to mark on a scale points that represent to you the verbal ratings: "Excellent", "Good", "Fair", "Poor", and "Terrible".

After all experimental runs and ratings have been completed, there will be an interview in which you will have an opportunity to discuss the reasons for some of your individual ratings.

As preparation for rating the importance of each of the helmet and mask characteristics, please read the following rating sheets, which you will be using to evaluate the helmet and masks.

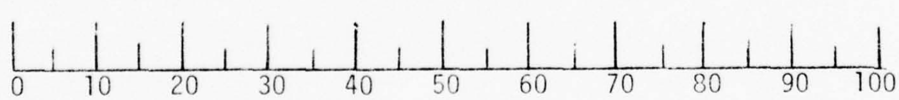
(2) Helmet and Mask Ratings. These ratings should be in terms of fleet use in fighter and attack aircraft, and should be based on your experience with the helmet and on your knowledge of fleet environments and requirements.

The rating scales are numbered 0 to 100, with low numbered ratings being worse and high numbered ratings being better. The points 0 and 100 on the scale represent extreme values for actual helmets to be considered for fleet use.

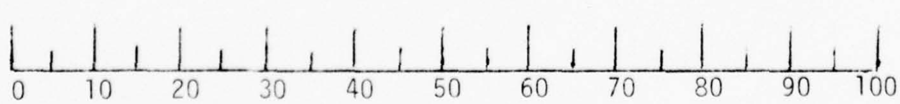
Please indicate your rating by a vertical mark through the scale line.

Considering times when quick and easy putting on and adjusting of helmet and mask may be desirable, how would you rate

EASE OF PUTTING ON AND ADJUSTING HELMET

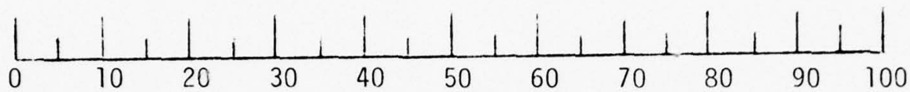


EASE OF PUTTING ON AND ADJUSTING MASK

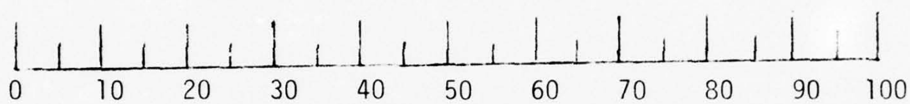


Considering the requirements for vision during each phase of the major missions, how would you rate

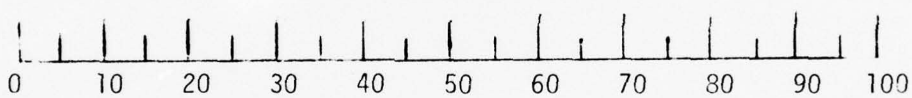
RANGE OF VISION: UP



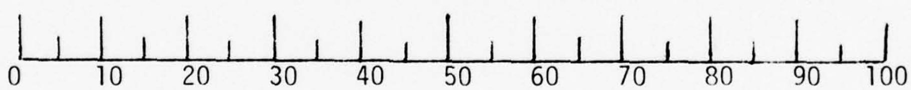
RANGE OF VISION: DOWN



RANGE OF VISION: LATERAL

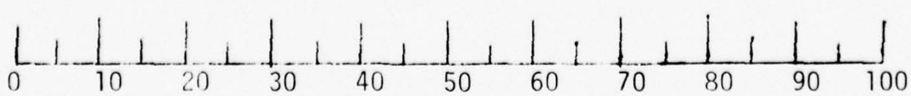


RANGE OF VISION: OVERALL



The apparent lightness of a helmet/mask combination is a complex function of weight and weight distribution. How light does this helmet/mask combination feel to you? (Remember, the lighter the helmet/mask combination feels, the larger the number on the rating scale.)

LIGHTNESS



During steady state or dynamic accelerations, helmets and/or masks may slip, reducing vision, breaking mask seal, and/or misaligning the VTAS system when used. Considering both VTAS and non-VTAS helmets together, how would you rate

HELMET STABILITY

0 10 20 30 40 50 60 70 80 90 100

MASK STABILITY

0 10 20 30 40 50 60 70 80 90 100

Across typical mission conditions, how would you rate this mask for

EASE OF BREATHING

0 10 20 30 40 50 60 70 80 90 100

In terms of communication adequacy, how would you rate

NOISE ATTENUATION

0 10 20 30 40 50 60 70 80 90 100

Head movements may be hindered by aircraft accelerations, hose and wiring connections, helmet bulk, weight, etc. How would you rate this helmet for

EASE OF HEAD MOVEMENTS

0 10 20 30 40 50 60 70 80 90 100

If VTAS:

EASE OF HOLDING TARGET

0 10 20 30 40 50 60 70 80 90 100

Keeping in mind the large range of operational environments, how would you rate

HELMET THERMAL COMFORT

0 10 20 30 40 50 60 70 80 90 100

Considering the pressure points which you may have noted, and considering missions of normal or longer duration, how would you rate

HELMET FIT

0 10 20 30 40 50 60 70 80 90 100

MASK FIT

0 10 20 30 40 50 60 70 80 90 100

Giving due consideration to all of the above variables, how would you rate

HELMET: OVERALL

0 10 20 30 40 50 60 70 80 90 100

MASK OVERALL

0 10 20 30 40 50 60 70 80 90 100

Prior to wearing any of the helmets, S rated the importance of helmet and mask characteristics on which the systems would be evaluated.

(3) Pre-Run Ratings of Importance of Variables. How important is each of the following variables when evaluating helmets? Please indicate your rating by a vertical mark through the scale line.

EASE OF PUTTING ON AND ADJUSTING HELMET

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

EASE OF PUTTING ON AND ADJUSTING MASK

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: UP

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: DOWN

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: LATERAL

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: OVERALL

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

LIGHTNESS

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

HELMET STABILITY

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

MASK STABILITY

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

EASE OF BREATHING

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

NOISE ATTENUATION

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

EASE OF HEAD MOVEMENTS

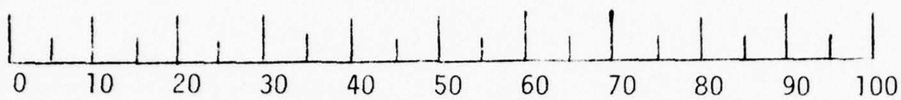
MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

If VTAS:

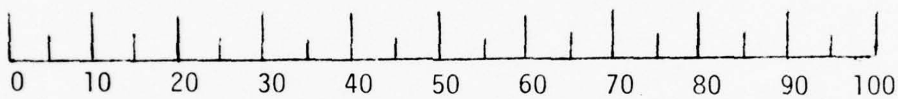
EASE OF HOLDING TARGET

MORE IMPORTANT →



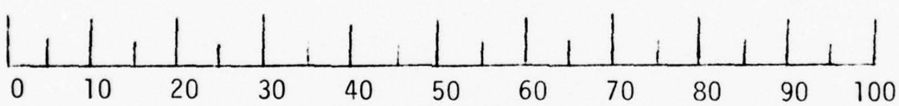
HELMET THERMAL COMFORT

MORE IMPORTANT →



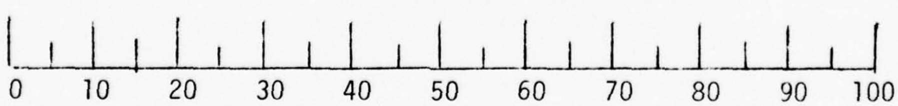
HELMET FIT

MORE IMPORTANT →



MASK FIT

MORE IMPORTANT →



b. Performance was measured for six helmet conditions: APH-6 with A-13A oxygen mask, HGU-35/P with high pressure mask, HGU-35/P with low pressure mask, VTAS-II with A-13A oxygen mask, VTAS-III with low pressure oxygen mask, and no helmet. S participated in six sessions, one helmet condition per session. The order of helmet conditions was randomized for each S. During the hour prior to each session, S wore the helmet to be

evaluated for that session. The purpose of the extended wearing time was to enable S to evaluate helmet comfort; also, during this time perimetry measurements were taken. S's range of visual field on a sphere centered about the nasion was measured for each helmet condition along the horizontal, vertical, and 45° inclined arcs.

c. Each data session consisted of two measures of performance: head mobility and sound attenuation, under two environments: 1Gz and 3Gz plateaus. The order of the performance tasks under the two G environments was randomized and replicated. Thus, each data session consisted of eight data runs.

(1) To measure head mobility a digit identification task was used. Digits presented by light-emitting diodes were located in three positions: overhead at a 73° angle of elevation in the mid-sagittal plane from the design eye point, and behind S, up to the left and right, laterally displaced 34° from the mid-sagittal plane and at a 33° angle of elevation from the design eye point. At the start of a head mobility trial, S was instructed to watch a horizontal display of lights located directly in front of him. Each light corresponded to one of the three digit positions. At the onset of a light, S was required to move his head as quickly as possible and identify the digit at the specified location. When S had identified the numeral, S responded by depressing the trigger switch which terminated the display. S then reported what numeral he had read. Time from the onset of a light to S's switch response was recorded for each trial. Nine trials, three at each display position, comprised each head mobility data run. Each trial was separated by 15 seconds, and the order of numerals presented and their location was randomized for each run. Due to the likelihood of motion sickness, S's were required to identify digits in the overhead location only under 3G, although the lights for left and right digits were still presented to maintain the discrimination reaction task under 3G.

(2) To evaluate the relative sound attenuation of the helmets, audiograms were taken. Four samples of band limited white noise with geometric mean frequencies approximating 500, 1K, 2K, and 4K Hz were presented to S through a gondola mounted speaker. The frequencies selected approximate the mid-range of four frequency bands of equal contribution to speech intelligibility. For each audiometric data run, each frequency band was presented to S for a 30 sec interval in which S bracketed the signal at threshold.

(3) During VTAS II and VTAS III helmet sessions, two additional runs were made. These runs combined both $3G_Z$ and buffet (±.3G @ 10 Hz). During a 3 minute period, S was instructed to keep a target within the VTAS reticle. S responded by pressing a trigger switch when the target was within the reticle and releasing the switch when the target was outside the reticle. Cumulative subjective estimates of time on target were recorded.

(4) During all data sessions, electromyographic (EMG) activity from the trapezius and sternocleidomastoid muscles was recorded to determine the muscular tension associated with wearing each helmet system. Following each data session, S completed the questionnaire rating the characteristics of the helmet system worn. Also, S was given the opportunity to give reasons for his ratings.

d. At the conclusion of the data sessions, S again rated the importance of each helmet/mask characteristic.

(1) Post-Run Rating of Importance of Variables. Considering your overall ratings of the helmets, what was the relative importance of each of the following variables in determining those ratings? Please indicate your rating by a vertical mark through the scale line.

EASE OF PUTTING ON AND ADJUSTING HELMET

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

EAST OF PUTTING ON AND ADJUSTING MASK

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: UP

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: DOWN

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: LATERAL

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

RANGE OF VISION: OVERALL

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

LIGHTNESS

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

HELMET STABILITY

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

MASK STABILITY

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

EASE OF BREATHING

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

NOISE ATTENUATION

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

EASE OF HEAD MOVEMENTS

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

If VTAS: EASE OF HOLDING TARGET

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

HELMET THERMAL COMFORT

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

HELMET FIT

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

MASK FIT

MORE IMPORTANT →

0 10 20 30 40 50 60 70 80 90 100

Considering the ratings that you have now completed, on the following scales mark points that represent to you the verbal ratings:

EXCELLENT

0 10 20 30 40 50 60 70 80 90 100

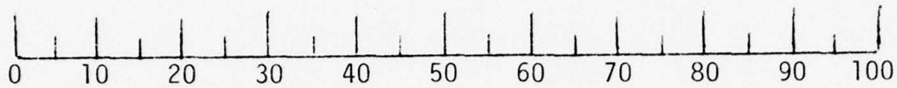
GOOD

0 10 20 30 40 50 60 70 80 90 100

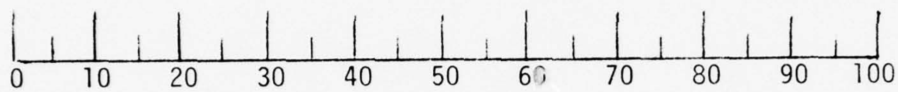
FAIR

0 10 20 30 40 50 60 70 80 90 100

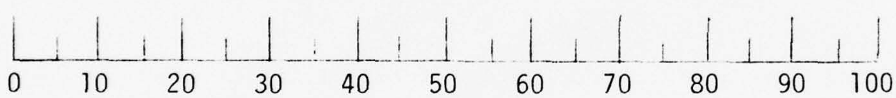
POOR



TERRIBLE



Considering your overall ratings of the helmets, indicate a point that represents to you the dividing line between "Unacceptable for Fleet Use"/ "Acceptable for Fleet Use".



Also, S assigned numerical ratings to the verbal descriptors: "Excellent", "Good", "Fair", "Poor", "Terrible", and "Acceptable for Fleet Use".

e. In an in-depth interview conducted after the final data collection session, S commented on those characteristics that he had rated as being very important and that he had also given an extremely high or low rating for a given helmet system. In addition, S ranked the helmet and masks as systems and the helments and masks separately. The interview concluded with a discussion of tradeoffs in evaluating systems and proposals for the ideal helmet/mask system.

TEST RESULTS

PHYSIOLOGICAL

The results presented in this section are strictly medical/physiological in nature and are merely responses shown by the test subjects to the stresses to which they were exposed. Although as much as possible was done to assure that all subjects would be exposed to the test profiles in an identical manner, personal variations among the subjects, particularly after hours, may introduce artifacts into the results. Therefore, one should hesitate before utilizing these results to buttress an argument in favor of or in opposition to a particular helmet.

These results represent preliminary findings concerning two types of data: Biochemical analyses on blood, drawn prior to and just after each centrifuge session, and straight physiological data, in this instance heart rates and intrahelmet and rectal temperatures. Since the biochemical data is, by far, the easier to analyze and report on, it will be covered first.

This report will be devoted to reporting the changes seen in the pre- and post-runs without trying to interpret them at this time. The only really significant biochemical changes noted over the entire subject population were significant increases in total protein and globulin fraction of the total protein in the blood, and a significant decrease in the serum glutamic-pyruvic transaminase level in the blood. However, looking at each subject, one by one, it was noted that Subject I had an increase in the globulin fraction of his circulating total protein concentration, and Subject II had a significant decrease in inorganic phosphate content without an accompanying increase in calcium concentration. Also, Subject IV had an increase in his total protein concentration as well as a significant drop in serum cholesterol level. One interesting sidelight in the biochemical results is the non-significant changes seen in the serum enzymes which were expected to show drastic shifts, especially in creatine-phosphokinase.

The hematological specimens also showed some significant changes which are unexplainable at this time. Looking at the entire subject population, a very large increase in the pre- vs post-test white blood cell count was seen, coupled with a significant increase in polymorphonuclear leucocytes (polys) and a significant decrease in lymphocytes (lymphs). Taking each subject one-by-one, Subject II showed a significant increase in polys with a decrease in lymphs. Subject III had a significant increase in white blood cells, but no significant changes in the numbers of any given type of white cell. Subject IV showed a significant increase in white cells, with a decrease in monocytes, but no change in polys or lymphs. He also showed a significant decrease in the specific gravity of his urine, meaning it became more dilute in the post samples. Subject IV was the only one showing any urinalysis changes of any significance.

The data on heart rates was very difficult to compile and analyze. Raw data was collected for six distinct time frames in each profile. Figure 6 shows the G_z - Time relationship for a typical profile, as well as the six center points of the collection time frames. The actual ECG signals were

TABLE 6

PAIRED-t ANALYSIS OF HEART RATE VS G_z-TIME PROFILE BETWEEN HELMETS

	I No Helmet	II APH-6D	III HGU-35/P (LP)	IV HGU-35/P (HP)	V VTAS II	VI VTAS III
Pre-Run						
I	---	2.44*	4.21**	3.15*	2.60*	1.93
II	---	---	2.27	2.18	0.95	0.33
III	---	---	---	1.19	1.84	2.74*
IV	---	---	---	---	4.52**	4.16**
V	---	---	---	---	---	0.95
6 G						
I	---	1.29	2.44*	1.98	1.56	1.28
II	---	---	2.18	2.01	0.83	0.15
III	---	---	---	0.75	9.33ΔΔ	2.35*
IV	---	---	---	---	3.23**	1.92
V	---	---	---	---	---	0.61
Valley						
I	---	1.53	1.90	1.72	1.45	2.94*
II	---	---	1.53	1.48	0.62	0.31
III	---	---	---	0.23	1.94	0.60
IV	---	---	---	---	1.55	0.75
V	---	---	---	---	---	0.01
4 G						
I	---	1.90	2.33	1.96	2.07	1.99
II	---	---	2.29	1.79	1.37	0.75
III	---	---	---	0.27	2.06	1.16
IV	---	---	---	---	1.66	0.89
V	---	---	---	---	---	1.20
Plateau						
I	---	2.01	2.82	2.25	1.33	1.50
II	---	---	3.06*	1.94	1.02	0.14
III	---	---	---	0.70	7.17ΔΔ	3.94**
IV	---	---	---	---	3.20**	2.57*
V	---	---	---	---	---	0.39

* -t = 0.050
** -t = 0.025

Δ -t = 0.010
ΔΔ -t = 0.005

TABLE 7

PAIRED-t ANALYSIS OF HEART RATE VS G_z-TIME PROFILE WITHIN HELMETS

	Pre (1)	6 G (2)	Valley (3)	4 G (4)	Plateau (5)	Post (6)
No Helmet						
Pre-Run	---	8.25$^{\Delta\Delta}$	3.53**	4.54$^{\Delta}$	3.40**	2.91*
6 G	---	---	0.70	0.15	4.39**	8.10$^{\Delta\Delta}$
Valley	---	---	---	0.99	2.03*	3.12*
4 G	---	---	---	---	4.74$^{\Delta}$	5.44$^{\Delta}$
Plateau	---	---	---	---	---	3.28**
Post	---	---	---	---	---	---
APH-6D						
Pre-Run	---	12.95$^{\Delta\Delta}$	4.20**	6.14$^{\Delta\Delta}$	2.43*	0.16
6 G	---	---	2.38*	3.24**	9.68$^{\Delta\Delta}$	14.78$^{\Delta\Delta}$
Valley	---	---	---	1.15	2.36*	3.43**
4 G	---	---	---	---	5.73$^{\Delta\Delta}$	6.02$^{\Delta\Delta}$
Plateau	---	---	---	---	---	2.80*
Post	---	---	---	---	---	---
HGU-35/P (LP)						
Pre-Run	---	22.29$^{\Delta\Delta}$	7.42$^{\Delta\Delta}$	9.65$^{\Delta\Delta}$	1.26	1.00
6 G	---	---	4.06**	1.60	8.85$^{\Delta\Delta}$	16.39$^{\Delta\Delta}$
Valley	---	---	---	0.55	4.82$^{\Delta\Delta}$	16.65$^{\Delta\Delta}$
4 G	---	---	---	---	5.38$^{\Delta}$	14.88$^{\Delta\Delta}$
Plateau	---	---	---	---	---	1.80
Post	---	---	---	---	---	---
HGU-35/P (HP)						
Pre-Run	---	14.99$^{\Delta\Delta}$	3.41**	8.87$^{\Delta\Delta}$	3.10*	5.23$^{\Delta}$
6 G	---	---	1.66	2.41*	5.32$^{\Delta}$	12.16$^{\Delta\Delta}$
Valley	---	---	---	0.79	1.33	2.68*
4 G	---	---	---	---	10.02$^{\Delta\Delta}$	7.27$^{\Delta\Delta}$
Plateau	---	---	---	---	---	2.07
Post	---	---	---	---	---	---

* -t = 0.050
** -t = 0.025

Δ -t = 0.010
ΔΔ -t = 0.005

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TABLE 7 (Cont'd)

PAIRED-t ANALYSIS OF HEART RATE VS G_z-TIME PROFILE WITHIN HELMETS

	Pre (1)	6 G (2)	Valley (3)	4 G (4)	Plateau (5)	Post (6)
VTAS-II						
Pre-Run	---	15.31$^{\Delta\Delta}$	7.33$^{\Delta\Delta}$	6.84$^{\Delta\Delta}$	6.42$^{\Delta\Delta}$	2.09
6 G	---	---	2.72*	2.87*	6.18$^{\Delta\Delta}$	6.96$^{\Delta\Delta}$
Valley	---	---	---	0.71	1.23	3.38**
4 G	---	---	---	---	2.96*	5.43$^{\Delta}$
Plateau	---	---	---	---	---	5.88$^{\Delta\Delta}$
Post	---	---	---	---	---	---
VTAS-III						
Pre-Run	---	10.56$^{\Delta\Delta}$	2.15	4.40**	4.12**	3.62**
6 G	---	---	1.84	3.76**	2.04	11.49$^{\Delta\Delta}$
Valley	---	---	---	0.41	0.98	1.99
Plateau	---	---	---	---	---	3.92**
Post	---	---	---	---	---	---

* -t = 0.050
** -t = 0.025
Δ -t = 0.010
$\Delta\Delta$ -t = 0.005

TABLE 8

ANALYSIS OF INTRAHELMET TEMPERATURES

	I	II	III	IV	V	VI
	No Helmet	APH-6D	HGU-35/P (LP)	HGU-35/P (HP)	VTAS II	VTAS III
THel						
I	---	---	---	---	---	---
II	---	---	1.14	1.26	0.41	1.60
III	---	---	---	0.63	1.17	0.57
IV	---	---	---	---	0.60	0.28
V	---	---	---	---	---	0.32
VI	---	---	---	---	---	---
TRec						
I	---	2.69*	2.08	3.65**	3.04	1.25
II	---	---	0.53	0.49	1.54	1.42
III	---	---	---	0.61	0.10	2.28
IV	---	---	---	---	0.45	8.53$^{\Delta\Delta}$
V	---	---	---	---	---	0.77
VI	---	---	---	---	---	---

* -t = 0.050
** -t = 0.025

Δ -t = 0.010
$\Delta\Delta$ -t = 0.005

TABLE 9

SUMMARY OF QUESTIONNAIRE DATA

VARIABLE	MEAN SUBJECTIVE IMPORTANCE OF VARIABLE	MEAN SCORE OF HELMET SYSTEM ON VARIABLE: APH-6D	HGU-35/P (HP)	HGU-35/P (LP)	VTAS II	VTAS III	STATISTICAL SIGNIFICANCE OF VARIABLE ACROSS HELMET SYSTEMS
EASE OF PUTTING ON AND ADJUSTING HELMET	61	79	84	61	85	74	
EASE OF PUTTING ON AND ADJUSTING MASK	77	50	35	34	42	49	
RANGE OF VISION: UP	93	60	71	86	69	32	
RANGE OF VISION: DOWN	88	38	66	84	44	78	$p<.05$
RANGE OF VISION: LATERAL	93	75	65	84	66	79	
RANGE OF VISION: OVERALL	94	59	61	85	64	68	
LIGHTNESS	91	32	88	91	39	55	$p<.05$
HELMET STABILITY	92	45	86	89	68	81	$p<.05$
MASK STABILITY	87	34	75	80	41	74	$p<.05$
EASE OF BREATHING	95	48	80	89	74	89	$p<.05$
NOISE ATTENUATION	81	70	65	76	90	85	$p<.05$
EASE OF HEAD MOVEMENTS	96	55	28	56	49	44	
EASE OF HOLDING TARGET	93	N/A	N/A	N/A	59	66	
HELMET THERMAL COMFORT	79	70	76	74	68	72	
HELMET FIT	92	52	81	69	84	78	
MASK FIT	92	26	44	65	40	66	$p<.05$

(All ratings are based on a scale from 0 to 100.)

manually counted over 10 second time intervals, utilizing "Xed" points on the figure as the center point. In this way, it was possible to cover essentially all of the major areas of the profile where heart rate changes could be expected. Following the actual compilation of this raw data, it was subjected to the standard Paired-t Test, but only results considered significant at the 90% level or greater were considered to be truly significant for purposes of this project. Tables 6 and 7 show the results of the two types of comparisons that were made on the data. Comparing the heart rates as a function of segment within the profile, there are significant differences between the 6 G peak periods, the plateau periods, and the post-profile periods, depending on which helmet was being tested. The most significant changes always seem to occur when comparing the HGU-35/P Low and High Pressure helmets with the VTAS II and III helmets. In all cases, the VTAS helmets showed the higher heart rates. These values could be due to a number of factors, but hypothesizing, essentially every subject complained that the helmet wanted to rotate under G, indicating poor center of gravity placement. This could be a highly significant factor in the heart rate differences since the men would have been forced to work harder in order to just maintain their heads in an upright position under G. The theory was initially considered that the weight of the helmets could account for the heart rate differences, and it may account for some of the difference, but the heart rate changes while the subjects wore the APH-6 do not bear out this theory. The heart rates are increased while wearing the APH-6, but not nearly to the extent that it increases with the VTAS's. The center of gravity theory would also fit the increased heart rates during the plateau. Although the G_Z level was not particularly high, the time under G_Z was very long and continuous effort had to be made to maintain the head-up position. Although the subjects were undergoing performance tasks during the plateau. the heart rates, while wearing the other helmets do not show the significant changes that are observed while wearing the VTAS II and III.

Comparing helmets during the pre-exposure condition, the no helmet condition was significantly different from nearly all the other helmeted conditions, as would be expected. However, the no helmet condition showed higher heart rates than the helmeted conditions. No definite reason can be given for this, but possibly there was a psychological element involved having to do with riding the centrifuge without the normal head protections. There was, however, still a significant heart rate difference between the HGU-35 helmets and the VTAS helmets even under the static condition, with the VTAS conditions showing the higher heart rates. Unfortunately, no explanation can be given for this occurrence. As a check on the data, the heart rates were compared "within helmets". All tests concerning a given helmet were compared with themselves, taking all combinations of parts of profiles; e.g., using the APH-6, comparisons were made as follows: pre- vs 6 G peak, pre- vs valley, pre- vs 4 G peak, pre- vs plateau, pre- vs post, 6 G peak vs valley, etc. In this way, it could be determined whether the parameter under study varied during a given experimental profile as it was expected to. A standard Paired-t Analysis was made of the heart rate data and changes, nearly all significant, did occur throughout the profiles. This analysis gives no real information about why the heart rates changed while wearing any particular helmet, but it does show that changes did take place during the profiles which lend more credence to the previous analysis "between helmets", by showing that differences reported there were the result of actual heart rate changes during the profiles and not artifacts.

In addition to the analyses on heart rates, the data concerning intrahelmet and rectal temperatures were studied and analyzed. Table 8 gives the results of the analysis of these parameters. The analysis of the intrahelmet temperature gave no useful information. Although there were definite temperature changes over time, none of them were significant enough to consider important. However, in several of the tests, the rectal temperatures did vary significantly but this information was of little value in analyzing the performance of the helmets. It does show that the subjective statements that the test subjects made in the past, that they "felt hot", do indeed have some basis in fact. Rectal temperature should be included in all future studies where full flight gear and long time periods in the gondola are involved, in order to verify or dispute this observation.

MEDICAL

The pre-run questionnaire (table 1) showed that the subjects were basically well, except for a few minor complaints. The number of hours slept before the runs ranged from six to eight hours, with an average of 6.8 hrs, the subjects feeling most completely rested after a "restful" sleep. The last food intake usually was breakfast or lunch with an average time since the last meal of 3.6 hours. The majority of subjects were not on medications, only mild pain relievers being taken the night before the run on two occasions, and one subject was on chronic tetracycline therapy for acne. Ethanol intake the night before the session was indulged in by only 36% of the subjects, and could be considered minor. Physical condition was gauged to be between good and excellent, with exercise every three to seven days. There were no chronic complaints except for one case each probable ethanol gastritis and hemorrhoids.

Before the ride, the subjects felt basically "fine" and interested in the program. Upon completing the ride, the comments varied widely, but seemed to center on approval of the "ride", and the aims of the program. The general post-run comments centered on being tired/fatigued, having suffered grayout, the problems with the adhesive tape on the biosensors, the discomfort caused by the over inflation of the G suit, dizziness, thirst, relaxed and "shaky" feelings. The rest of the variety of responses on physiological effects, as well as responses about the helmets themselves, can be found in table 2. The APH-6 and the HGU-35/P helmets, in retrospect, seemed to be the most unacceptable, by far.

Immediately post-run, the subjects mostly complained of dizziness, fatigue, abdominal discomfort, and neck pain/stiffness (table 3). At the 24 hr post-run level, these comments centered primarily on fatigue and neck muscle fatigue.

The pre-run physical examination (table 4) demonstrated some instances of retropharygeal hyperemia and nasal hyperemia, which showed an improvement in about half the subjects at the post-run examination. The pulmonary symptoms, such as wheezing and rales, generally disappeared after the G experience although two subjects acquired these signs in the post-run period. The post-run period primarily demonstrated cutaneous hyperemia and ecchymosis from the G experience and some nucal and mesogastric pain. Two subjects suffered second degree retroauricular burns from the use of an inappropriate electrical system in the cutaneous microphone system.

The blood pressure showed no significant change pre-post run, neither supine nor upright. However, the diastolic values pre-post run, when compared in the standing and supine position, were significant to the 0.1 level. The change in the pulse rate from an average of 79.5 (pre) to 89.1 (post) was significant to the 0.005 level, as in the temperature change (98.5-99.2). There was no significant change in respiratory rates.

The pre-post run EKG changes can be seen in table 5, the significant change being the "T" changes in III, usually going from a (±) configuration to a more biphasic or negative configuration. Minor "p" changes were also noted. One subject demonstrated a change in the location of the AV pacemaking node (stimulus location), before G exposure, and another showed a definite loss of voltage in II, AVr, and AVf, post G exposure. Follow-ups are being done on both of these patients.

HUMAN FACTORS

a. Friedman analyses of variance of ranks were used to analyze the data unless stated otherwise. S's range of visual field was not restricted by any of the helmets along the horizontal arc. Along the 45° inclined arcs the range of visual field was greatest for the no-helmet condition ($p<.05$); no differential effect among the helmets was found, however. Range of vision along the vertical arcs varied significantly with helmet condition ($p<.01$). Again, the no-helmet condition offered the least restriction; the VTAS III and APH-6 were the most restrictive.

b. The time scores for the digit identification task under 1Gz were subjected to an analysis of variance. Although helmet conditions had no statistically significant effect on the data, a weak trend was observed. The smallest mean time occurred under the no-helmet condition, the largest under the APH-6 helmet condition. Location of digits did affect time scores ($p<.01$); digits in the overhead position were identified in the shortest time. Although helmet conditions also had no statistically significant effect on digit identification times under 3G, mean time for the APH-6 helmet condition was the largest.

c. Analysis of the audiometric data revealed that the relative intensity of the signal at threshold varied with helmet condition under 1Gz ($p<.01$) and under 3Gz ($p<.05$). Under both G conditions, the mean threshold was lowest for the no-helmet condition. The APH-6 helmet offered the least sound attenuation under both G conditions; under the 1Gz condition the mean threshold was comparable to the no-helmet condition. The HGU-35P high pressure and VTAS II offered the best sound attenuation.

d. A correlated t-test showed cumulative time on target was greater for the VTAS II helmet than for the VTAS III helmet ($p<.01$), although most of the difference can be attributed to data from a single subject who did very poorly while wearing the VTAS III helmet.

e. Relative EMG data, recorded from the trapezius during audiometric testing showed no effect due to helmet condition. Although statistical significance was not attained, mean EMG data across G conditions showed the least muscle activity under the no-helmet condition and the most with the APH-6 helmet.

A summary of the data from the questionnaires is presented in table 9.

S's ratings of helmet systems on each variable were analyzed to determine if the ratings on any variable differentiated the helmet systems. The variables on which helmet systems significantly differed are also indicated in table 9.

Weighted ratings for the helmet systems on each variable were obtained by multiplying the mean rating given by Ss by the mean importance of that variable. These weighted ratings did reflect differences among the helmet systems ($p<.01$). The mean of the weighted ratings indicated the helmet systems ranked from the best to the worst were: (1) HGU-35P low pressure, (2) VTAS III, (3) HGU-35P high pressure, (4) VTAS II, and (5) APH-6.

Although the overall ratings of the helmets did not differentiate among the helmets, the trend of the means indicated the helmets from best to worst were: (1) HGU-35P high pressure, (2) HGU-35P low pressure, (3) VTAS III, (4) APH-6, and (5) VTAS II. The overall ratings of the masks did distinguish the masks ($p<.05$), the low pressure mask was superior to both the high pressure and A-13A mask.

On the basis of S's criteria of acceptability for fleet use and their overall ratings for the helmets and masks, a majority of Ss considered only the HGU-35P high pressure and VTAS III helmets, and the low pressure mask acceptable for fleet use.

Ss' comments from the interviews were compiled and any mentioned deficiency of the systems has been presented in the following summary of helmet and mask problems:

SUMMARY OF INTERVIEWS: HELMET AND MASK PROBLEMS

[1]One S reports.
[2]Two Ss report.
[3]Three Ss report.
[4]Four Ss report.

HELMET SYSTEM: APH-6

EASE OF PUTTING ON AND ADJUSTING HELMET

Helmet fit is difficult to adjust.[2]
Centering helmet, aligning earcups, and matching pads with earcups are difficult.[1]

EASE OF PUTTING ON AND ADJUSTING MASK

Suspension system is deficient.[3]
Grooves are spaced too far apart for small adjustments.[1]
Mask is not aligned with helmet; thus mask rotates upward against nose.[1]
Side fittings are difficult to seat.[1]
Mask cannot be adjusted for a good seal.[3]
Mask does not seal across cheeks.[1]

RANGE OF VISION: UP

Bridge of helmet is visible.[3]
Helmet rotates forward into view.[3]

RANGE OF VISION: DOWN

Mask/hose system is in view.[3]
Instruments are hidden from view during catapult shot.[2]

RANGE OF VISION: LATERAL

Edge of helmet is visible.[3]

LIGHTNESS

Helmet/mask system is heavy.[4]
Mask is too heavy; CG is at forward edge of visor due to weight distribution.[1]
All weight is centered on crown of head; weight seems to increase noticeably with time.[1]

HELMET STABILITY

Helmet shifts forward.[3]
Helmet shifts when head is moved backward.[1]
Helmet shifts laterally.[2]
Helmet shifts whenever resistance is applied.[1]
Helmet shifts because helmet rests on one point, the crown of the head.[1]
Helmet stability with comfort is impossible.[1]

MASK STABILITY

Mask pulls down under G.[4]
Shifting is due to weight of mask.[1]
Communications is difficult.[1]
Mask rides up when head is moved downward.[1]

EASE OF BREATHING

Mask cannot be adjusted for a good seal.[3]
Air seal is broken under G.[2]
Broken seal interferes with communications.[1]
Good seal with comfort is impossible to obtain.[2]
Exhalation is heavy.[2]
Too much ambient noise is present in breathing.[1]

NOISE ATTENUATION

Hearing is difficult; sound level is noisy.[1]

EASE OF HEAD MOVEMENTS

Helmet shifts.[3]
Weight restricts movement under G.[2]
Oxygen hose restricts upward movement.[2]
Head must leave headrest for upward movements.[1]
Oxygen hose restricts downward movement.[2]
Mask and hose are too stiff and press against chest.[1]
ICS hook-up restricts lateral movements.[3]
Communication cord gets caught in equipment.[2]
Forward movements are restricted.[1]

HELMET THERMAL COMFORT

Helmet is warm.[3]
Warmth is due to effort to hold head up.[1]
Sweat comes down over face.[1]

HELMET FIT

Helmet causes pressure points.[3]
All weight is centered on crown of head because fore/aft pads are not tight.[1]
Edges of earcup press on ear; earcups are too small.[1]
Helmet presses against back of head.[1]
Helmet presses across forehead.[1]
Comfort with stability is impossible.[1]
Edgeroll on nape of neck comes off.[1]
Pads cannot accommodate all head shapes and sizes, and require extensive refitting due to deterioration.[1]

MASK FIT

Mask causes pressure points.[3]
Mask presses on bridge of nose.[3]
Mike presses on teeth, lips and chin.[3]
Rubber strap is uncomfortable.[2]
Strap interferes with communications under G.[1]
Strap presses at bottom of nose.[1]
Hard cup presses under chin and makes swallowing, chewing and clearing ears difficult.[1]
Mask is too bulky.[2]
Good seal that is comfortable is impossible to obtain.[2]

HELMET SYSTEM: HGU-35P (HP)

EASE OF PUTTING ON AND ADJUSTING HELMET

No adverse comments were given.

EASE OF PUTTING ON AND ADJUSTING MASK

Mask is difficult to adjust.[4]
Male/female connection demands exact fitting.[2]
In-flight adjustment is impossible.[2]
Left side locking is indefinite; left side does not "click" when in place.[1]
Mask sits on an angle.[2]
Holding clips are too high on helmet.[1]
Mask cannot be sealed.[1]

RANGE OF VISION: UP

Helmet rotates forward into view when coil of hose at back stops upward movement of head.[1]

RANGE OF VISION: DOWN

Mask is too bulky.[1]
Mask raises cheek height.[1]
Instruments are hidden from view during catapult shot.[1]

RANGE OF VISION: LATERAL

Ends of straps are in view.[2]
Visor tracks and sides of helmet are in view.[3]

LIGHTNESS

Mask/hose assembly is heavy.[2]

HELMET STABILITY

Helmet shifts forward and rotationally when coil of hose stops movement of head.[1]

MASK STABILITY

Mask slips down due to improper fit.[2]
Mask sits on an angle.[1]

EASE OF BREATHING

Respiration is noisy.[4]
Hissing noise is present.[2]
Hissing interferes with communications.[1]
Air entering during inhalation is very loud.[1]
Leak in fitting is present.[3]
Air is bled during non-inhalation phase.[1]
Exhalation valve has flutter.[1]
Mask cannot be sealed.[1]

NOISE ATTENUATION

Internal noise of oxygen system interferes with attenuation of external noise.[3]

EASE OF HEAD MOVEMENT

Coil of hose attached at back of helmet restricts movement.[4]
Coil is bulky.[3]
Coil is inflexible.[3]
Lateral movements are restricted.[3]
Upward movements to right and left are restricted.[2]
Movement requires hose to move to one side or the other.[1]

HELMET THERMAL COMFORT

Helmet is warm.[2]
Sweat is present.[2]

HELMET FIT

Helmet causes pressure points.[3]
Foam causes ridge behind ears and on right side of forehead.[1]
Mask pulling on helmet causes pressure point on lower back of head.[1]
Oxygen hose chafes on back of neck.[1]

MASK FIT

Mask causes pressure points.[3]
Mask causes pressure point on bridge of nose.[2]
Mask causes pressure point on jawline and upper cheeks.[1]
Pressure points on nose and chin are caused by mask being too short and pulling up on chin and down on nose.[1]
Mask is not narrow enough.[1]

HELMET SYSTEM: HGU-35P (LP)

EASE OF PUTTING ON AND ADJUSTING HELMET

Earcup fit is difficult to adjust.[1]
Spacers are too large.[1]
Earcups do not come down low enough, particularly on left side, and are difficult to align.[1]
Chin strap snap is difficult to fasten.[1]

EASE OF PUTTING ON AND ADJUSTING MASK

Left side suspension is deficient.[4]
Suspension pulls in wrong direction, down on left side and up on right side.[2]
Bulge in oxygen hose, and leak on left side result.[1]
Releases are difficult to find; pins are too delicate and difficult to align.[1]
Left side is difficult to attach, especially when helmet is being worn.[2]

RANGE OF VISION: UP

No adverse comments were given.

RANGE OF VISION: DOWN

Mask/hose system is in view.[1]
Bulge in oxygen hose obstructs vision down to left.[1]

RANGE OF VISION: LATERAL

Helmet sides and visor cover are visible.[2]

LIGHTNESS

No adverse comments were given.

HELMET STABILITY

Helmet shifts forward with backward movements of head against LPA-1.[1]
Helmet moves straight downward onto head under G due to fit of liner.[1]
Inner liner is not large enough for lateral stability.[1]

MASK STABILITY

Mask shifts to side because oxygen connection cannot be adjusted adequately.[1]

EASE OF BREATHING

Exhalation valve sticks.[1]
Inhalation valve has fluttering.[1]
Twisting of mask by suspension system precludes obtaining a good seal.[1]

NOISE ATTENUATION

Sound level is noisy.[1]

EASE OF HEAD MOVEMENTS

Oxygen connection at back restricts movement upward and to the left.[4]
Connection hangs up on LPA-1.[3]
Connection interferes with putting head against headrest.[3]
Oxygen connection restricts movement to the right.[1]

HELMET THERMAL COMFORT

Helmet is warm.[2]
Black liner absorbs sun.[2]

HELMET FIT

Helmet causes pressure points.[3]
Routing of hose inside helmet causes ridge above left ear.[1]
Edgeroll on inner liner causes ridge on forehead.[1]
Trapped air in earcup causes pressure on ear.[1]
Communication cord chafes back.[1]
Head and inner liner do not sit straight in helmet due to oxygen and communication cord entry block at back.[1]

MASK FIT

Suspension system detracts from fit.[2]
Mask is too short.[1]

HELMET SYSTEM: VTAS II

EASE OF PUTTING ON AND ADJUSTING HELMET

Earcups are difficult to position.[1]

EASE OF PUTTING ON AND ADJUSTING MASK

Good seal is difficult to obtain.[4]
Mask is difficult to seat at top of mask.[2]
Mask is difficult to seal under chin.[1]
Stiff, heavy mask does not conform to face.[2]
Suspension pulls in wrong direction.[1]

RANGE OF VISION: UP

Helmet is visible.[2]
Helmet rotates forward into view.[1]

RANGE OF VISION: DOWN

Mask is too massive.[2]
Mask sits too high.[1]
Vision down to side is restricted.[1]

RANGE OF VISION: LATERAL

Helmet sides protrude.[3]

LIGHTNESS

Helmet/mask system is heavy.[4]
CG is forward.[1]

HELMET STABILITY

Helmet shifts forward.[1]
Helmet shifts laterally.[1]
Helmet shifts rotationally.[1]

MASK STABILITY

Mask slips down under G.[3]
Mask slips under chin and presses mike against teeth; thus, swallowing is difficult.[1]

EASE OF BREATHING

Good seal is difficult to obtain.[4]
System is insufficient for deep breathing.[1]
Seal breaks under G.[1]
Mask leaks at sides during exhalation.[1]
Exhalation is heavy.[1]
Mask leaks under right eye.[1]

NOISE ATTENUATION

No adverse comments were given.

EASE OF HEAD MOVEMENTS

VTAS power cord restricts head movements.[4]
Rear corner of VTAS assembly restricts lateral movements; pilot must lean forward to turn to right or left.[2]
Weight and CG restricts lifting head.[1]

HELMET THERMAL COMFORT

Helmet is warm.[3]
Head is warm under visor.Helmet is warm due to fatigue caused by weight of helmet.[1]
Sweat is present.[1]
Black liner absorbs sun.[1]

EASE OF HOLDING TARGET

Reticle vibrates.[2]
Holding target is difficult.[2]
CG and helmet mass make holding the target difficult.[2]
Rotation of helmet hinders holding the target.[1]
Restrictions of oxygen hose and VTAS power cord hinder holding the target.[1]

HELMET FIT

Helmet causes pressure points.[2]
Too small earcup exerts pressure on earlobe.[1]
Mask pulls helmet edgeroll onto neck.[1]

MASK FIT

Mask causes pressure points.[3]
Mask presses under nose and on cheeks.[1]
Rubber strap presses on upper lip.[1]
Mask presses on bridge of nose.[1]
Mask presses chin.[2]
Mask is too hard and inflexible.[1]
Mike presses against mouth, lip and teeth.[2]
There is not enough space for inside components of mask, in particular, the mike.[1]
Mask pushes chin strap into larynx.[1]

HELMET SYSTEM: VTAS III

EASE OF PUTTING ON AND ADJUSTING HELMET

Helmet is not flexible outward at ears.[2]

EASE OF PUTTING ON AND ADJUSTING MASK

Helmet is not adjustable on left side.[2]
Too much adjustment is needed to maintain balance of helmet on head.[1]
Angle of fitting is too low.[1]
Oxygen hose bulges and mask tilts down from attachment points when mask is tightened.[1]

RANGE OF VISION: UP

Helmet is visible.[2]

RANGE OF VISION: DOWN

Corrugated hose on left side is in view.[1]
Strap on right side is in view.[1]
Mask is in view.[1]
Mask sits up high and raises cheek height.[1]

RANGE OF VISION: LATERAL

Visor tracks are visible.[2]
Oxygen hose bulges under left eye.[1]

LIGHTNESS

CG is forward.[2]
Helmet/mask system is heavy.[2]
Hose connection forces head forward and causes neck strain.[1]

HELMET STABILITY

Hose at back forces helmet forward.[1]
Head shifts laterally due to helmet width and ears not being tight.[1]

MASK STABILITY

Mask slips down under G.[1]
Right side strap used to tighten mask comes loose.[1]

EASE OF BREATHING

Sharp inhalation over demands system.[1]
Breathing is too easy; hose could come out and pilot would not know he was breathing ambient.[1]
Mask comes away from face under G.[1]

NOISE ATTENUATION

No adverse comments were given.

EASE OF HEAD MOVEMENT

Oxygen hose restricts upward movements.[3]
Oxygen hose restricts movements to the left.[1]
VTAS cord restricts movement.[2]
Weight restricts upward movements.[1]

EASE OF HOLDING TARGET

Reticle bounces.[2]
Forward CG is noticeable when pilot tries to maintain head position.[1]

HELMET THERMAL COMFORT

Helmet is warm.[2]
Warmth is caused by effort to hold up head.[1]
Sweat is present.[1]
More breathing area is needed.[1]
Black liner absorbs sun.[1]

HELMET FIT

Helmet causes pressure points.[3]
Mask pushes chin strap against larynx; choking sensation results.[1]
Earcups need larger holes and more spacers.[1]
Hard ridge presses on right side from temple to ear.[1]
Pressure is exerted at left forward edge of liner.[1]

MASK FIT

Mask causes pressure points.[2]
Pressure is exerted on top of nose.[2]
Nose grip holes are too high and thus, are useless.[1]

CONCLUSIONS

MEDICAL/PHYSIOLOGICAL

From the data on the medical/physiological parameters monitored, it is possible to draw several conclusions:

(1) There were significant heart rate changes "among helmets" comparing sections of the profile against each other. The most obvious were always between the HGU-35/P's and the VTAS's.

(2) Significant changes in heart rate were noted when comparing "within helmets" indicating that the changes discussed in (1) were not artifacts.

(3) The helmet thermistor gave no useful data other than the fact that no significant temperature changes were noted in any of the helmets.

(4) Rectal temperature measurements did show some significant temperature increases giving objective backing to subjective comments about "feeling hot", often made by our test subject both in this study and in previous studies.

(5) These data alone should not be used to make concrete judgments about any of the helmets due to possible interference of subject variation, but combining this with the performance data should give some valuable results.

HUMAN FACTORS

Along the 45° inclined arcs, the range of visual field was greatest for the no-helmet condition; however, no differential effect among the helmets was found.

Range of vision along the vertical arcs varied significantly with helmet condition; the no-helmet condition offered the least restriction while the VTAS III and APH-6 were the most restrictive.

Although helmet conditions also had no statistically significant effect on digit identification times under 3G, the mean time for the APH-6 helmet condition was the largest.

The APH-6 helmet offered the least sound attenuation under both the 1Gz and the 3Gz conditions; under the 1Gz condition, the mean threshold was comparable to the no-helmet condition. The HGU-35/P (high pressure) and the VTAS II offered the best sound attenuation.

Cumulative time on target was greater for the VTAS II helmet than for the VTAS III helmet, although most of the difference can be attributed to data from a single subject who did poorly while wearing the VTAS III helmet.

Relative EMG data showed no effect due to helmet condition; however, mean EMG data across G conditions showed the least muscle activity under the no-helmet condition and the most with the APH-6 helmet.

Many design changes are being incorporated into the basic HGU-35/P low pressure and high pressure helmets as a result of the centrifuge tests. The low pressure modifications are as follows:

(1) A more flexible oxygen service hose will be provided.

(2) The rear oxygen service hose disconnect will be moved to a center location on the lower rear of the helmet. This disconnect will be faired into the shell profile to avoid encumbrance with the seat headrest. It will also have a two finger unlocking device to prevent accidental unlocking.

(3) A lower profile oxygen hose/helmet disconnect will be provided. It will incorporate a check valve that will close when the disconnect is not connected.

(4) An elliptical oxygen hose instead of a round hose will be routed inside the helmet shell.

(5) The ear-seal location of the skin contact capacitor microphone will be relocated within the eardome.

(6) The oxygen mask suspension system will be redesigned to provide more adjustability.

(7) The oxygen mask/helmet disconnect will be redesigned for a more positive locking.

(8) The combination exhalation/inhalation valve will incorporate an improved flapper valve material and will be protected against saliva and dirt by a cover.

The HGU-35/P high pressure helmet will also be modified in the following ways:

(1) A more flexible high pressure oxygen hose will be provided to eliminate encumbrance between the wearer and the aircraft seat so that the hose will not interfere with the full range of the wearer's required head movements.

(2) The rear oxygen service hose disconnect will be relocated to the center lower rear of the helmet shell and will be faired into the profile of the shell to avoid encumbrance with the seat headrest. It will also have a two finger unlocking device to prevent accidental unlocking.

(3) The rear high pressure oxygen hose disconnect will incorporate a check valve that will close when the disconnect is not connected.

(4) The miniature oxygen regulator will be relocated from inside the mask to a position within the shell profile in the center lower rear of the helmet shell.

(5) The ear-seal location of the skin contact capacitor microphone will be relocated within the eardome.

(6) The oxygen mask shell will be reconfigured to reduce its profile and the exhalation valve will be moved to the left side. It will become similar to the low pressure mask shell.

(7) The mask/helmet disconnects (right and left sides) will incorporate a suspension system similar to that of the low pressure helmet.

(8) The tubing within the shell between the rear regulator and the mask/helmet disconnect will be redesigned.

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